700mA Low Noise High Current LED Charge Pump

FEATURES

- **High Efficiency Operation: 1x, 1.5x or 2x Boost Modes with Automatic Mode Switching**
- **Ultralow Dropout I_{LED} Current Control**
- **Output Current up to 700mA**
- **Low Noise Constant Frequency Operation***
- Wide V_{IN} Range: 2.9V to 4.4V
- Open/Shorted LED Protection
- LED Disconnect in Shutdown
- Low Shutdown Current: 2.5µA
- 4% LED Current Programming Accuracy
- Automatic Soft-Start Limits Inrush Current
- No Inductors
- Tiny Application Circuit (All Components <1mm Profile)
- 3mm × 3mm 10-Lead DFN Package

APPLICATIONS

- LED Torch/Camera Light Supply for Cell Phones, PDAs and Digital Cameras
- General Lighting and/or Flash/Strobe Applications

DESCRIPTION

The LTC®3215 is a low noise, high current charge pump DC/DC converter designed to power high current LEDs. The part includes an accurate programmable current source capable of driving loads up to 700mA from a 2.9V to 4.4V input. Low external parts count (two flying capacitors, one programming resistor and two bypass capacitors) makes the LTC3215 ideally suited for small, battery-powered applications.

Built-in soft-start circuitry prevents excessive inrush current during start-up. High switching frequency enables the use of small external capacitors. LED current is programmed with an external resistor. The LED is disconnected from V_{IN} during shutdown.

An ultralow dropout current source maintains accurate LED current at very low I_{LED} voltages. Automatic mode switching optimizes efficiency by monitoring the voltage across the LED current source and switching modes only when I_{LED} dropout is detected. The LTC3215 is available in a low profile 3mm × 3mm 10-Lead DFN package.

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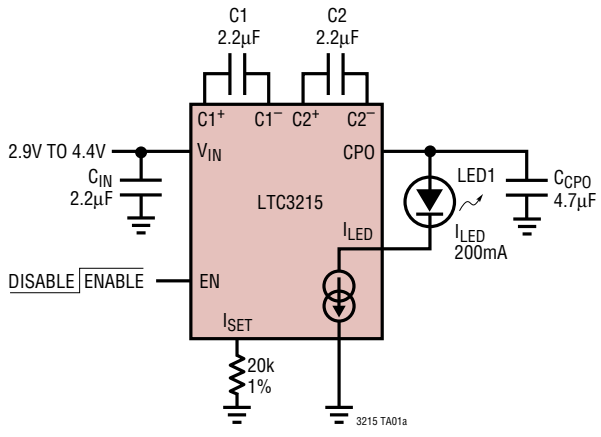
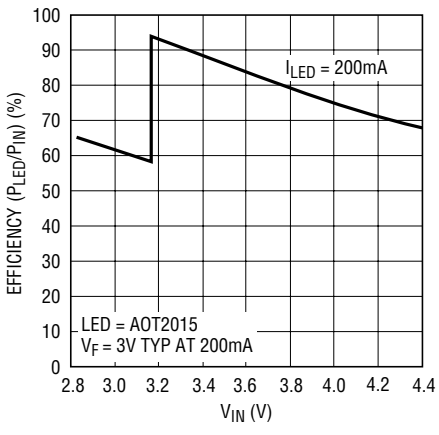
*Protected by U.S. Patents including 6411531.

TYPICAL APPLICATION



LED1: AOT2015

Efficiency vs V_{IN}

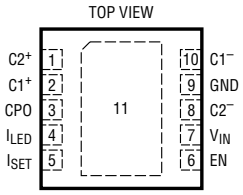


ABSOLUTE MAXIMUM RATINGS

(Note 1)

V_{IN} to GND ..... –0.3V to 5.5V
CPO to GND ..... –0.3V to 5.5V
EN ..... –0.3V to V_{IN} + 0.3V
I_{CPO}, I_{ILED} (Note 2) 1000mA
CPO Short-Circuit Duration ..... Indefinite
Storage Temperature Range ..... –65°C to 125°C
Operating Temperature Range (Note 3) .. –40°C to 85°C

PACKAGE/ORDER INFORMATION



DD PACKAGE
10-LEAD (3mm × 3mm) PLASTIC DFN
T_{JMAX} = 125°C, θ_{JA} = 43°C/W
EXPOSED PAD (PIN 11) IS GND, MUST BE SOLDERED TO PCB

ORDER PART NUMBER	DD PART MARKING
LTC3215EDD	LBPX

Order Options Tape and Reel: Add #TR
Lead Free: Add #PBF Lead Free Tape and Reel: Add #TRPBF
Lead Free Part Marking: http://www.linear.com/leadfree/

Consult LTC Marketing for parts specified with wider operating temperature ranges.

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = 3.6V, C_{IN} = C1 = C2 = 2.2µF, C_{CPO} = 4.7µF.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Input Power Supply						
V_{IN} Operating Voltage		●	2.9		4.4	V
I_{VIN} Operating Current	I_{CPO} = 0mA, 1x Mode I_{CPO} = 0mA, 1.5x I_{CPO} = 0mA, 2x Mode			300 7 9.2		µA mA mA
I_{VIN} Shutdown Current	EN = LOW			2.5	7	µA
LED Current						
LED Current Ratio (I_{LED}/I_{SET})	I_{LED} = 200mA to 600mA	●	3139	3270	3400	mA/mA
I_{LED} Dropout Voltage	Mode Switch Threshold, I_{LED} = 200mA			120		mV
Mode Switching Delay (LED Warmup Time)				2.5		ms
LED Current On Time	EN↑ to LED Current On			130		µs
Charge Pump (CPO)						
1x Mode Output Voltage	I_{CPO} = 0mA			V_{IN}		V
1.5x Mode Output Voltage	I_{CPO} = 0mA			4.6		V
2x Mode Output Voltage	I_{CPO} = 0mA			5.1		V
1x Mode Output Impedance				0.25		Ω
1.5x Mode Output Impedance	V_{IN} = 3.4V, V_{CPO} < 4.6V			1.5		Ω
2x Mode Output Impedance	V_{IN} = 3.2V, V_{CPO} < 5.1V			1.7		Ω
CLK Frequency		●	0.6	0.9	1.2	MHz
EN						
High Level Input Voltage (V_{IH})		●	1.4			V
Low Level Input Voltage (V_{IL})		●			0.4	V
Input Current (I_{IH})		●	–1		1	µA
Input Current (I_{IL})		●	–1		1	µA

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = 3.6V, C_{IN} = C1 = C2 = 2.2µF, C_{CPO} = 4.7µF.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
I_{SET}						
V_{ISET}	I_{SET} = 50µA	●	1.195	1.22	1.245	V
I_{ISET}		●			225	µA

Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

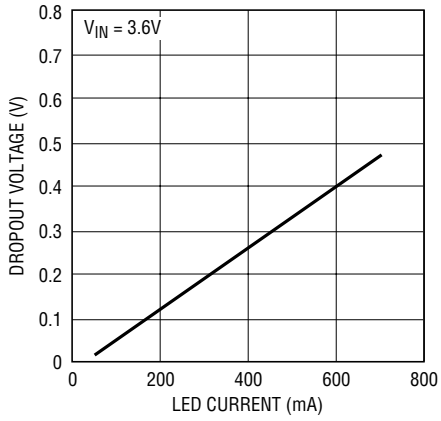
Note 2: Based on long-term current density limitations. Assumes an operating duty cycle of ≤ 10% under absolute maximum conditions for durations less than 10 seconds. Max current for continuous operation is 350mA.

Note 3: The LTC3215E is guaranteed to meet performance specifications from 0°C to 70°C. Specifications over the –40°C to 85°C ambient operating temperature range are assured by design, characterization and correlation with statistical process controls.

TYPICAL PERFORMANCE CHARACTERISTICS

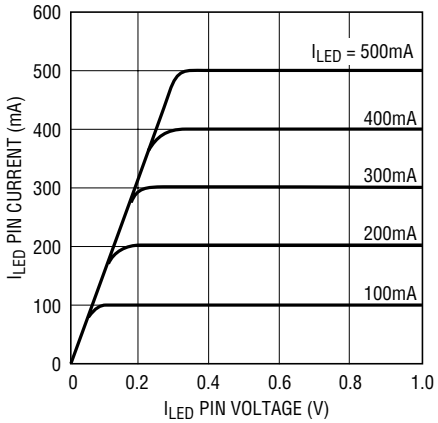
(T_A = 25°C unless otherwise specified)

I_{LED} Dropout Voltage vs LED Current



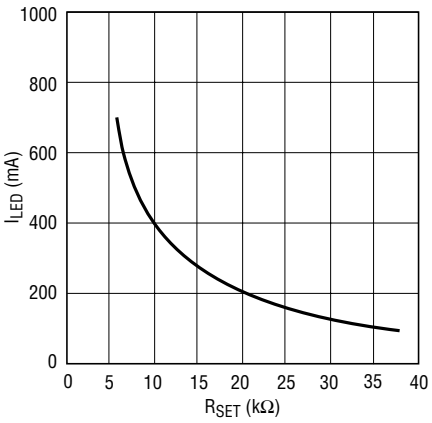
3216 G01

I_{LED} Pin Current vs I_{LED} Pin Voltage



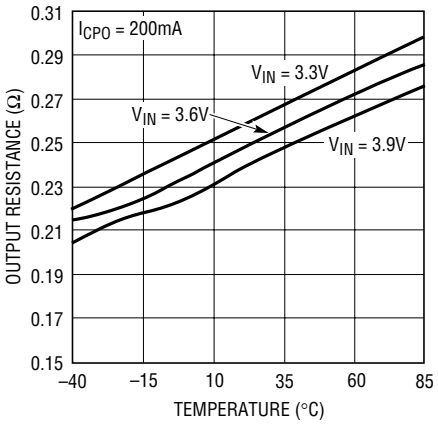
3216 G02

I_{LED} vs R_{SET}



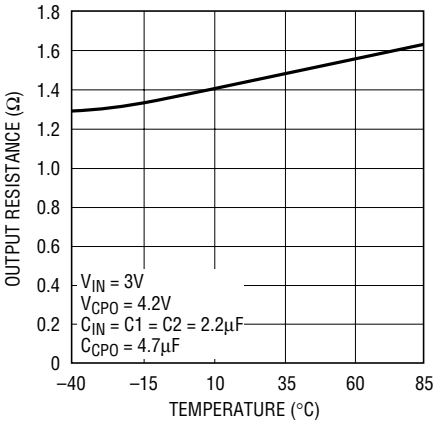
1573 G06

1x Mode Charge Pump Open-Loop Output Resistance vs Temperature



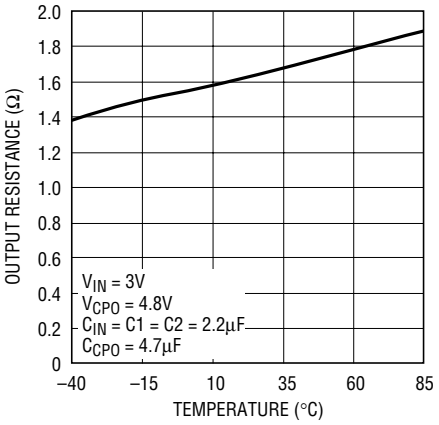
3216 G07

1.5x Mode Charge Pump Open-Loop Output Resistance ($1.5V_{IN} – V_{CPO}$)/I_{CPO} vs Temperature



3216 G05

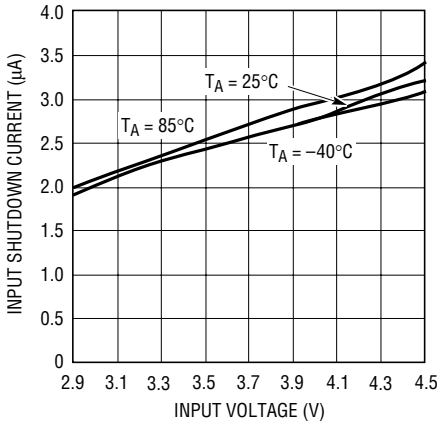
2x Mode Charge Pump Open-Loop Output Resistance ($2V_{IN} – V_{CPO}$)/I_{CPO} vs Temperature



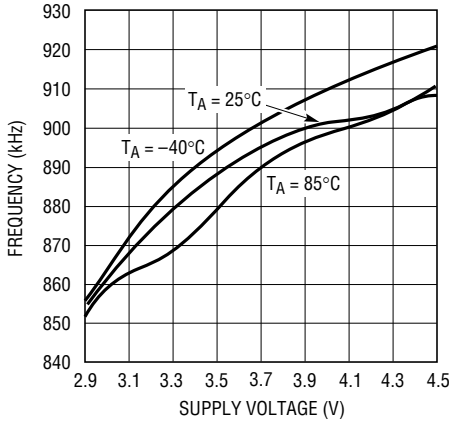
3216 G06

TYPICAL PERFORMANCE CHARACTERISTICS (T_A = 25°C unless otherwise specified)

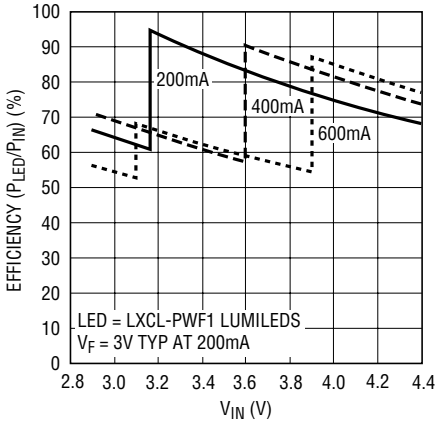
Input Shutdown Current vs Input Voltage



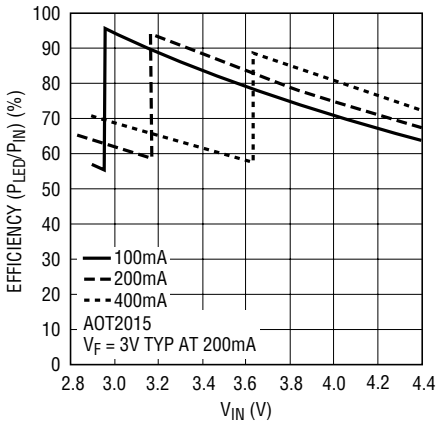
Oscillator Frequency vs Supply Voltage



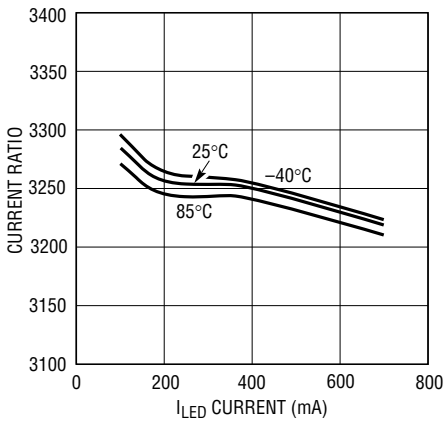
Efficiency vs V_{IN}



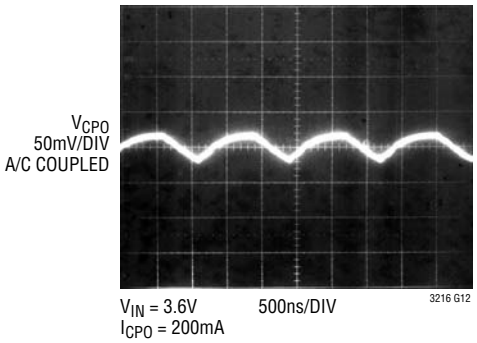
Efficiency vs V_{IN}



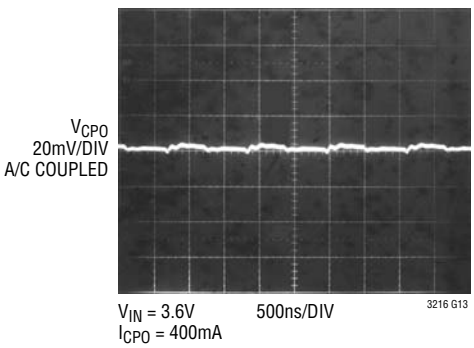
I_{SET}/I_{LED} Current Ratio vs I_{LED} Current



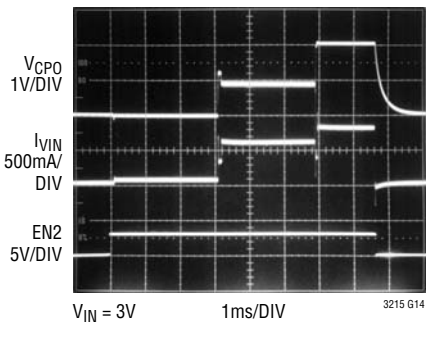
1.5x Mode CPO Output Ripple



2x Mode CPO Output Ripple



Charge Pump Mode Switching and Input Current (I_{LED} = 400mA)



PIN FUNCTIONS

C2+, C1+, C2–, C1– (Pins 1, 2, 8, 10): Charge Pump Flying Capacitor Pins. A 2.2µF X5R or X7R ceramic capacitor should be connected from C1+ to C1– and from C2+ to C2–.

CPO (Pin 3): Output. CPO is the output of the Charge Pump. This pin may be enabled or disabled using the EN input. A 4.7µF X5R or X7R ceramic capacitor is required from CPO to GND.

I_{LED} (Pin 4): Output. I_{LED} is the LED current source output. The LED is connected between CPO (anode) and I_{LED} (cathode). The current into the I_{LED} pin is set by the programming resistor connected from I_{SET} to GND.

I_{SET} (Pin 5): LED Current Programming Resistor Pin. The I_{SET} pin will servo to 1.22V. A resistor connected between this pin and GND is used to set the LED current level. Connecting a resistor of 2k or less will cause the LTC3215 to enter overcurrent shutdown mode.

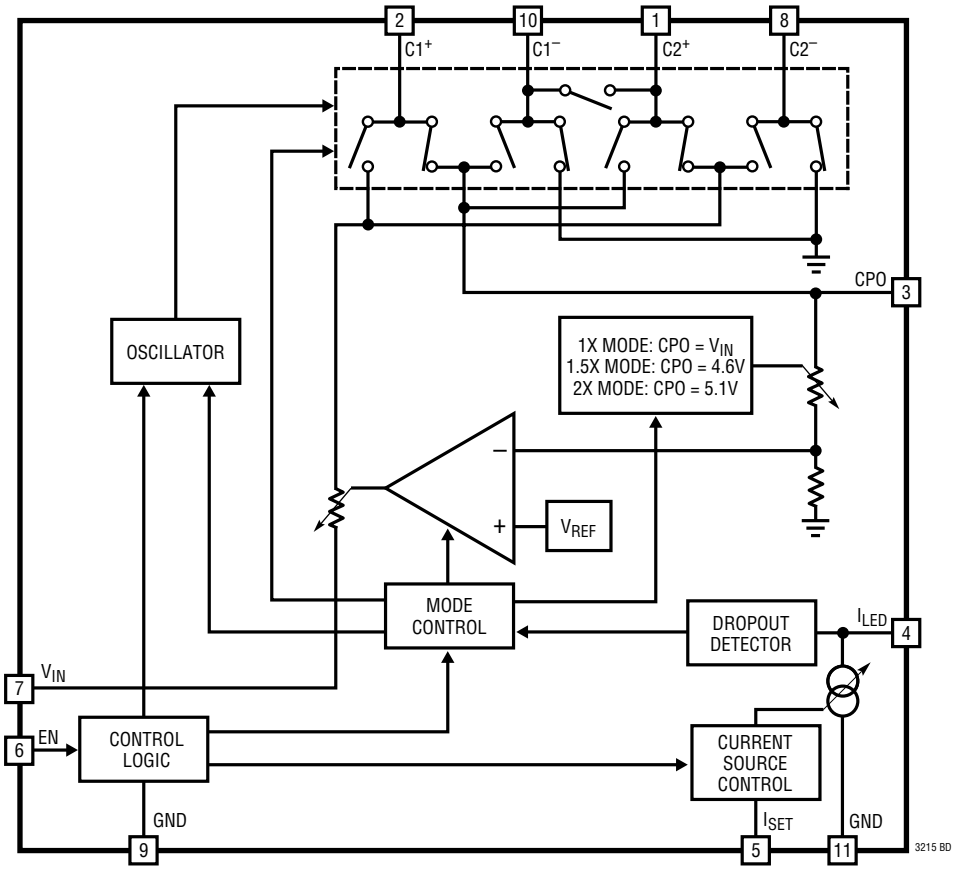
EN (Pin 6): Input. The EN is used to enable the part or put it into shutdown mode.

V_{IN} (Pin 7): Power. Supply voltage for the LTC3215. V_{IN} should be bypassed with a 2.2µF or greater low impedance ceramic capacitor to GND.

GND (Pin 9): Charge Pump Ground. This pin should be connected directly to a low impedance ground plane.

EXPOSED PAD (Pin 11): Control Signal Ground. This pad must be soldered to a low impedance ground plane for optimum thermal and electrical performance.

BLOCK DIAGRAM



OPERATION

The LTC3215 uses a fractional switched capacitor charge pump to power a high current LED with a programmed regulated current. The part starts up into the 1x mode. In this mode, V_{IN} is directly connected to CPO. This mode provides maximum efficiency and minimum noise. The LTC3215 will remain in this mode until the LED current source begins to dropout. When dropout is detected, the LTC3215 will switch to 1.5x mode after a soft-start period. Any subsequent dropout detected will cause the part to enter 2x mode. The part may be reset to 1x mode by bringing the part into shutdown mode and then reenabling the part.

A two phase nonoverlapping clock activates the charge pump switches. In the 2x mode, the flying capacitors are charged on alternate clock phases from V_{IN}. While one capacitor is being charged from V_{IN}, the other is stacked on top of V_{IN} and connected to the output. Alternatively, in the 1.5x mode the flying capacitors are charged in series during the first clock phase, and stacked in parallel on top of V_{IN} on the second clock phase. This sequence of charging and discharging the flying capacitors continues at a free running frequency of 900kHz (typ).

The current delivered to the LED load is controlled by the internal programmable current source. The value of this current may be selected by choosing the appropriate programming resistor. The resistor is connected between the I_{SET} pin and GND. The resistor value needed to attain the desired current level can be determined by Equation 1.

$$R_{SET} = 3990/I_{LED} \quad (1)$$

A resistor value of 2k or less (e.g., a short-circuit) will cause the LTC3215 to enter overcurrent shutdown mode. This mode will prevent damage to the part by shutting down the high power sections of the chip.

Regulation is achieved by sensing the voltage at the CPO pin and modulating the charge pump strength based on the error signal. The CPO regulation voltages are set internally, and are dependent on the charge pump mode as shown in Table 1.

Table 1. Charge Pump Output Regulation Voltages

CHARGE PUMP MODE	V_{CPO}
1.5x	4.6V
2x	5.1V

In shutdown mode all circuitry is turned off and the LTC3215 draws a very low current from the V_{IN} supply. Furthermore, CPO is weakly connected to V_{IN}. The LTC3215 enters shutdown mode when the EN pin is brought low. Since EN is a high impedance CMOS input it should never be allowed to float. To ensure that its state is defined, it must always be driven with valid logic levels.

Thermal Protection

The LTC3215 has built-in overtemperature protection. Thermal shutdown circuitry will shutdown the I_{LED} output when the junction temperature exceeds approximately 150°C. It will re-enable the I_{LED} output once the junction temperature drops back to approximately 135°C. The LTC3215 will cycle in and out of thermal shutdown indefinitely without latch up or damage until the heat source is removed.

Soft-Start

To prevent excessive inrush current during start-up and mode switching, the LTC3215 employs built-in soft-start circuitry. Soft-start is achieved by increasing the amount of current available to the output charge storage capacitor linearly over a period of approximately 250µs.

Charge Pump Strength

When the LTC3215 operates in either the 1.5x mode or 2x mode, the charge pump can be modeled as a Thevenin-equivalent circuit to determine the amount of current available from the effective input voltage and effective open-loop output resistance, R_{OL}(Figure 1).

OPERATION

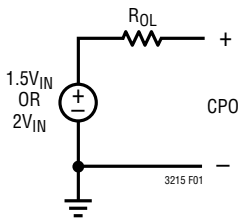


Figure 1. Charge Pump Open-Loop Thevenin-Equivalent Circuit

R_{OL} is dependent on a number of factors including the oscillator frequency, flying capacitor values and switch resistances.

From Figure 1, we can see that the output current is proportional to:

$$(1.5V_{IN} – CPO)/R_{OL} \text{ or } (2V_{IN} – CPO)/R_{OL} \quad (2)$$

in the 1.5x mode or 2x mode respectively.

LED Current Programming

The LTC3215 includes an accurate, programmable current source that is capable of driving LED currents up to 350mA continuously and up to 700mA for pulsed operation. Pulsed operation may be achieved by toggling the EN pin. In either continuous or pulsed operation, proper board layout is required for effective heat sinking.

The current may be programmed using a single external resistor. Equation 1, used to calculate the resistor value from the desired current level is repeated below:

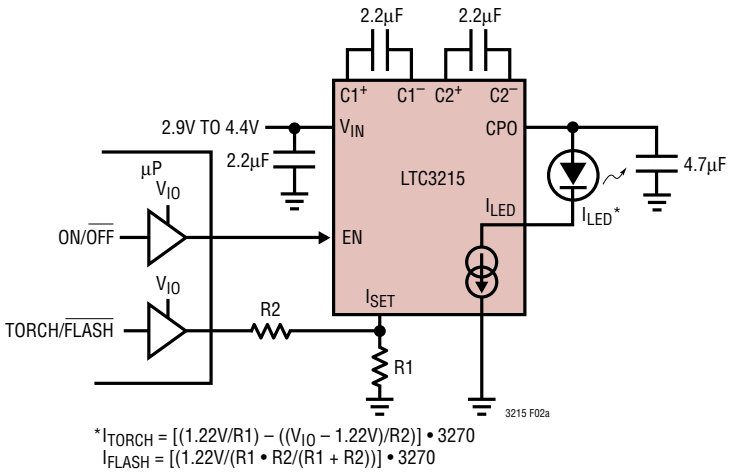
$$R_{SET} = 3990/I_{LED} \quad (1)$$

For applications requiring multiple current levels, several schemes may be used to change the resistance for the R_{SET} resistor. Figure 2 shows two such schemes. The circuit in Figure 2a uses the I/O output of a microcontroller to switch a second resistor (R2) in parallel or series with R1, changing the effective I_{SET} current. Alternatively, the circuit in Figure 2b uses a pulse-width modulator (PWM) to vary the current through R_{SET}, which changes the LED current.

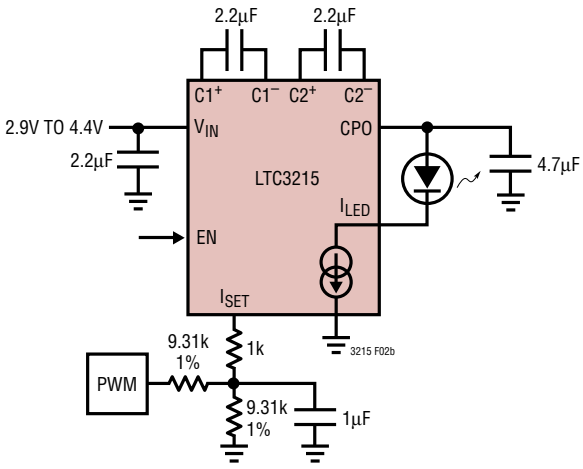
Mode Switching

The LTC3215 will automatically switch from 1x mode to 1.5x mode, and subsequently from 1.5x mode to 2x mode whenever a dropout condition is detected at the I_{LED} pin. The part will wait approximately 2ms before switching to the next mode. This delay allows the LED to warm up and reduce its forward voltage which may remove the dropout condition.

In order to reset the part back into 1x mode, the LTC3215 must be brought into shutdown (EN = LOW). Immediately after the part has been brought to shutdown, it may be enabled into the 1x mode via the EN pin. An internal comparator will not allow the main switches to connect V_{IN} and CPO in 1x mode until the voltage at the CPO pin has decayed to less than or equal to the voltage at the V_{IN} pin.



(2a)



(2b)

Figure 2

APPLICATIONS INFORMATION

V_{IN}, CPO Capacitor Selection

The value and type of capacitors used with the LTC3215 determine several important parameters such as regulator control loop stability, output ripple, charge pump strength and minimum start-up time.

To reduce noise and ripple, it is recommended that low equivalent series resistance (ESR) ceramic capacitors be used for both C_{VIN} and C_{CPO}. Tantalum and aluminum capacitors are not recommended because of their high ESR.

The value of C_{CPO} directly controls the amount of output ripple for a given load current. Increasing the size of C_{CPO} will reduce the output ripple at the expense of higher start-up current. The peak-to-peak output ripple for 1.5x mode is approximately given by the expression:

$$V_{RIPPLE(P-P)} = I_{OUT}/(3f_{OSC} \bullet C_{CPO}) \quad (3)$$

Where f_{OSC} is the LTC3215's oscillator frequency (typically 900kHz) and C_{CPO} is the output storage capacitor.

Both the style and value of the output capacitor can significantly affect the stability of the LTC3215. As shown in the block diagram, the LTC3215 uses a control loop to adjust the strength of the charge pump to match the current required at the output. The error signal of this loop is stored directly on the output charge storage capacitor. The charge storage capacitor also serves as the dominant pole for the control loop. To prevent ringing or instability, it is important for the output capacitor to maintain at least 2.2µF of actual capacitance over all conditions.

Likewise, excessive ESR on the output capacitor will tend to degrade the loop stability of the LTC3215. The closed loop output resistance of the LTC3215 is designed to be 76mΩ. For a 100mA load current change, the error signal will change by about 7.6mV. If the output capacitor has 76mΩ or more of ESR, the closed-loop frequency response will cease to roll off in a simple one-pole fashion and poor load transient response or instability could result. Multilayer ceramic chip capacitors typically have exceptional ESR performance. MLCCs combined with a tight board layout will yield very good stability. As the value of C_{CPO} controls the amount of output ripple, the value of C_{VIN} controls the amount of ripple present at the input pin (V_{IN}). The input current to the LTC3215 will be relatively constant while the charge pump is on either the input charging phase or the output charging phase but will drop to zero during the clock nonoverlap times. Since the nonoverlap time is small (~15ns), these missing "notches" will result in only a small perturbation on the input power supply line. Note that a higher ESR capacitor such as tantalum will have higher input noise due to the input current change times the ESR. Therefore, ceramic capacitors are again recommended for their exceptional ESR performance. Input noise can be further reduced by powering the LTC3215 through a very small series inductor as shown in Figure 3. A 10nH inductor will reject the fast current notches, thereby presenting a nearly constant current load to the input power supply. For economy, the 10nH inductor can be fabricated on the PC board with about 1cm (0.4") of PC board trace.

Flying Capacitor Selection

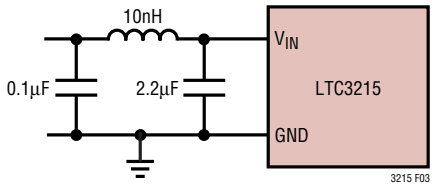


Figure 3. 10nH Inductor Used for Input Noise Reduction (Approximately 1cm of Wire)

Warning: Polarized capacitors such as tantalum or aluminum should never be used for the flying capacitors since their voltage can reverse upon start-up of the LTC3215. Ceramic capacitors should always be used for the flying capacitors.

The flying capacitors control the strength of the charge pump. In order to achieve the rated output current it is necessary to have at least 2.2µF of actual capacitance for each of the flying capacitors. Capacitors of different materials lose their capacitance with higher temperature and voltage at different rates. For example, a ceramic capacitor made of X7R material will retain most of its capacitance from –40°C to 85°C whereas a Z5U or Y5V style capacitor will lose considerable capacitance over that range. Z5U and Y5V capacitors may also have a very poor voltage coefficient causing them to lose 60% or more of their capacitance when the rated voltage is applied. Therefore, when comparing different capacitors, it is often more appropriate to

APPLICATIONS INFORMATION

compare the amount of achievable capacitance for a given case size rather than comparing the specified capacitance value. For example, over rated voltage and temperature conditions, a 1µF, 10V, Y5V ceramic capacitor in a 0603 case may not provide any more capacitance than a 0.22µF, 10V, X7R available in the same case. The capacitor manufacturer's data sheet should be consulted to determine what value of capacitor is needed to ensure minimum capacitances at all temperatures and voltages.

Table 2 shows a list of ceramic capacitor manufacturers and how to contact them.

Table 2. Recommended Capacitor Vendors

AVX	www.avxcorp.com
Kemet	www.kemet.com
Murata	www.murata.com
Taiyo Yuden	www.t-yuden.com
Vishay	www.vishay.com
TDK	www.tdk.com

Layout Considerations and Noise

Due to its high switching frequency and the transient currents produced by the LTC3215, careful board layout is necessary. A true ground plane and short connections to all capacitors will improve performance and ensure proper regulation under all conditions. An example of such a layout is shown in Figure 4.

The flying capacitor pins $C1^+$, $C2^+$, $C1^-$ and $C2^-$ will have very high edge rate waveforms. The large dv/dt on these pins can couple energy capacitively to adjacent PCB runs. Magnetic fields can also be generated if the flying capacitors are not close to the LTC3215 (i.e., the loop area is large). To decouple capacitive energy transfer, a Faraday shield may be used. This is a grounded PCB trace between the sensitive node and the LTC3215 pins. For a high quality AC ground, it should be returned to a solid ground plane that extends all the way to the LTC3215.

The following guidelines should be followed when designing a PCB layout for the LTC3215.

- The Exposed Pad should be soldered to a large copper plane that is connected to a solid, low impedance ground plane using plated, through-hole vias for proper heat sinking and noise protection.
- Input and output capacitors (C_{IN} and C_{CPO}) must also be placed as close to the part as possible.
- The flying capacitors must also be placed as close to the part as possible. The traces running from the pins to the capacitor pads should be as wide as possible.
- V_{IN}, CPO and I_{LED} traces must be made as wide as possible. This is necessary to minimize inductance, as well as provide sufficient area for high current applications.
- LED pads must be large and should be connected to as much solid metal as possible to ensure proper heat sinking.

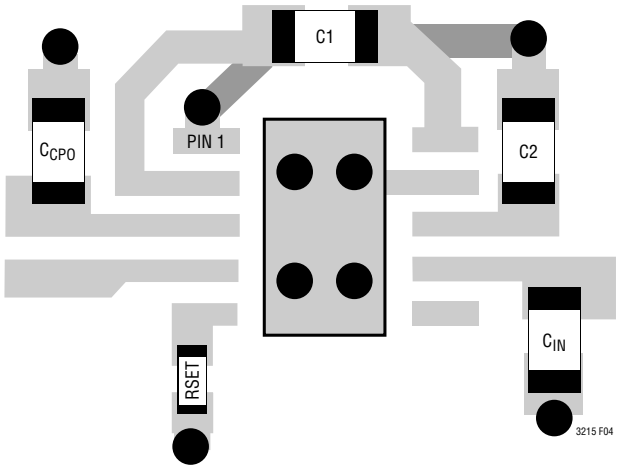


Figure 4. Example Board Layout

APPLICATIONS INFORMATION

Power Efficiency

To calculate the power efficiency (η) of a white LED driver chip, the LED power should be compared to the input power. The difference between these two numbers represents lost power whether it is in the charge pump or the current sources. Stated mathematically, the power efficiency is given by:

$$\eta \equiv \frac{P_{LED}}{P_{IN}} \quad (4)$$

The efficiency of the LTC3215 depends upon the mode in which it is operating. Recall that the LTC3215 operates as a pass switch, connecting V_{IN} to CPO, until dropout is detected at the I_{LED} pin. This feature provides the optimum efficiency available for a given input voltage and LED forward voltage. When it is operating as a switch, the efficiency is approximated by:

$$\eta \equiv \frac{P_{LED}}{P_{IN}} = \frac{V_{LED} \bullet I_{LED}}{V_{IN} \bullet I_{IN}} \approx \frac{V_{LED}}{V_{IN}} \quad (5)$$

since the input current will be very close to the LED current.

At moderate to high output power, the quiescent current of the LTC3215 is negligible and the expression above is valid.

Once dropout is detected at the I_{LED} pin, the LTC3215 enables the charge pump in 1.5x mode.

In 1.5x boost mode, the efficiency is similar to that of a linear regulator with an effective input voltage of 1.5 times the actual input voltage. This is because the input current for a 1.5x charge pump is approximately 1.5 times the load current. In an ideal 1.5x charge pump, the power efficiency would be given by:

$$\eta_{IDEAL} \equiv \frac{P_{LED}}{P_{IN}} = \frac{V_{LED} \bullet I_{LED}}{V_{IN} \bullet 1.5 I_{LED}} \approx \frac{V_{LED}}{1.5 V_{IN}} \quad (6)$$

Similarly, in 2x boost mode, the efficiency is similar to that of a linear regulator with an effective input voltage of 2 times the actual input voltage. In an ideal 2x charge pump, the power efficiency would be given by:

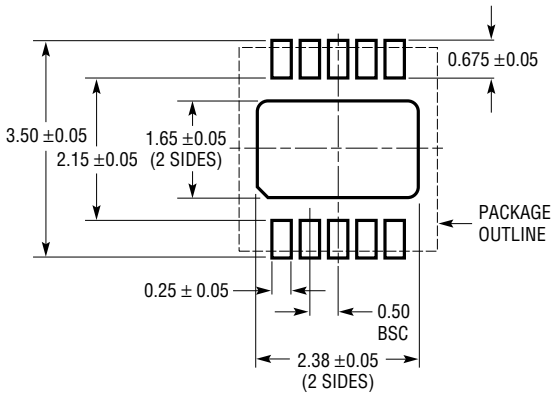
$$\eta_{IDEAL} \equiv \frac{P_{LED}}{P_{IN}} = \frac{V_{LED} \bullet I_{LED}}{V_{IN} \bullet 2 \bullet I_{LED}} \approx \frac{V_{LED}}{2 \bullet V_{IN}} \quad (7)$$

Thermal Management

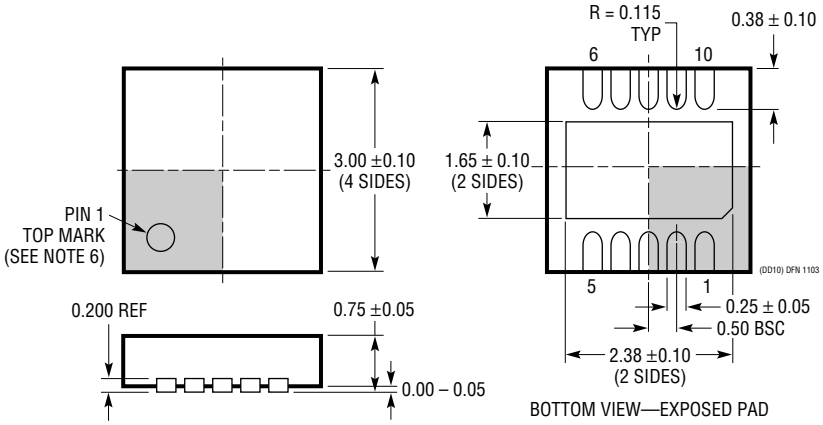
For higher input voltages and maximum output current, there can be substantial power dissipation in the LTC3215. If the junction temperature increases above approximately 150°C, the thermal shutdown circuitry will automatically deactivate the output. To reduce maximum junction temperature, a good thermal connection to the PC board is recommended. Connecting the Exposed Pad to a ground plane and maintaining a solid ground plane under the device can reduce the thermal resistance of the package and PC board considerably.

PACKAGE DESCRIPTION

DD Package
10-Lead Plastic DFN (3mm × 3mm)
(Reference LTC DWG # 05-08-1698)



RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS



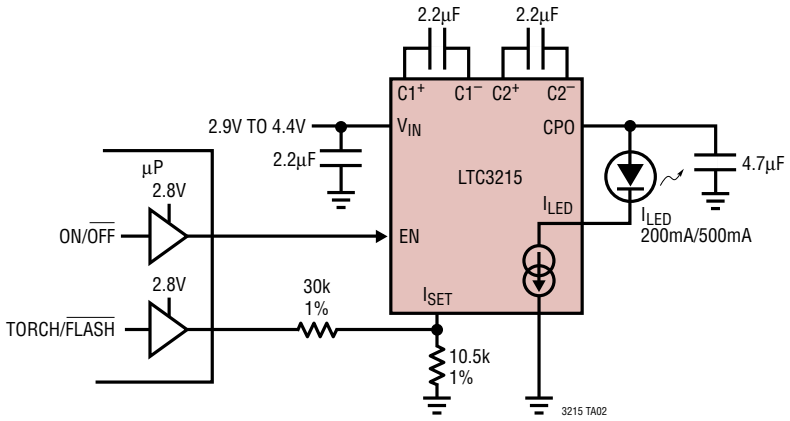
BOTTOM VIEW—EXPOSED PAD

NOTE:
1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE M0-229 VARIATION OF (WEED-2). CHECK THE LTC WEBSITE DATA SHEET FOR CURRENT STATUS OF VARIATION ASSIGNMENT
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE SOLDER PLATED
6. SHADED AREA IS ONLY A REFERENCE FOR PIN 1 LOCATION ON THE TOP AND BOTTOM OF PACKAGE

Information furnished by Linear Technology Corporation is believed to be accurate and reliable. However, no responsibility is assumed for its use. Linear Technology Corporation makes no representation that the interconnection of its circuits as described herein will not infringe on existing patent rights.

TYPICAL APPLICATION

High Power Camera Light and Flash



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1618	Constant Current, 1.4MHz, 1.5A Boost Converter	V_{IN}: 1.6V to 18V, $V_{OUT(MAX)}$ = 36V, I_Q = 1.8mA, I_{SD} < 1µA MS Package
LT1961	1.5A (I_{SW}), 1.25MHz, High Efficiency Step-Up DC/DC Converter	V_{IN}: 3V to 25V, $V_{OUT(MAX)}$ = 35V, I_Q = 0.9mA, I_{SD} < 6µA MS8E Package
LTC3205	250mA, 1MHz, Multi-Display LED Controller	V_{IN}: 2.8V to 4.5V, $V_{OUT(MAX)}$ = 5.5V, I_Q = 50µA, I_{SD} < 1µA DFN Package
LTC3206	400mA, 800kHz, Multi-Display LED Controller	V_{IN}: 2.8V to 4.5V, $V_{OUT(MAX)}$ = 5.5V, I_Q = 50µA, I_{SD} < 1µA DFN Package
LTC3214	500mA Camera LED Charge Pump	93% Efficiency, V_{IN}: 2.9V to 4.4V, 1x/1.5x/2x Boost Modes, 3mm × 3mm DFN Package
LTC3217	600mA Low Noise Multi-LED Camera Light Charge Pump	Up to 4 LEDs, 92% Efficiency, V_{IN}: 2.9V to 4.5V, 1x/1.5x/2x Boost Modes, Independent Torch and Flash I_{SET} and Enable Pins, 3mm × 3mm QFN Package
LTC3216	1A Low Noise High Current LED Charge Pump with Independent Flash/Torch Current Control	V_{IN}: 2.9V to 4.4V, $V_{OUT(MAX)}$ = 5.5V, I_Q = 300µA, I_{SD} < 2.5µA DFN Package
LTC3440/LTC3441	600mA/1.2A I_{OUT}, 2MHz/1MHz, Synchronous Buck-Boost DC/DC Converter	V_{IN}: 2.4V to 5.5V, $V_{OUT(MAX)}$ = 5.25V, I_Q = 25µA/50µA, I_{SD} <1µA MS/DFN Packages
LTC3443	600mA/1.2A I_{OUT}, 600kHz, Synchronous Buck-Boost DC/DC Converter	V_{IN}: 2.4V to 5.5V, $V_{OUT(MAX)}$ = 5.25V, I_Q = 28µA, I_{SD} <1µA DFN Package
LTC3453	1MHz, 800mA Synchronous Buck-Boost High Power LED Driver	$V_{IN(MIN)}$: 2.7V to 5.5V, $V_{IN(MAX)}$: 2.7V to 4.5V, I_Q = 2.5mA, I_{SD} < 6µA QFN Package
LT3467/LT3467A	1.1A (I_{SW}), 1.3/2.1MHz, High Efficiency Step-Up DC/DC Converters with Integrated Soft-Start	V_{IN}: 2.4V to 16V, $V_{OUT(MAX)}$ = 40V, I_Q = 1.2mA, I_{SD} < 1µA ThinSOT Package
LT3479	3A, 42V, 3.5MHz Boost Converter	V_{IN}: 2.5V to 24V, $V_{OUT(MAX)}$ = 40V, I_Q = 2µA, I_{SD} < 1µA DFN, TSSOP Packages

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